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Bracketing Mid-Pliocene Sea Surface Temperature: Maximum and Minimum Possible Warming

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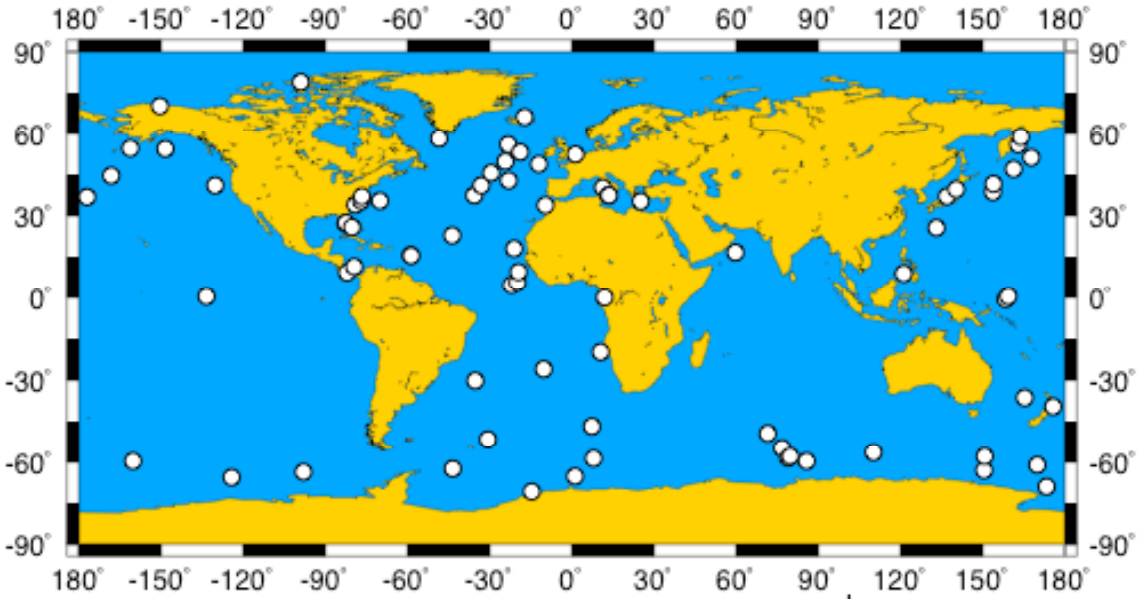

Map showing data localities used in this reconstruction.

Abstract

Estimates of sea surface temperature (SST) from ocean cores reveal a warm phase of the Pliocene between about 3.3 and 3.0 Mega-annum's (Ma). Pollen records from land based cores and sections, although not as well dated, also show evidence for a warmer climate at about the same time. Increased greenhouse forcing and altered ocean heat transport is the leading candidates for the underlying cause of Pliocene global warmth. However, despite being a period of global warmth, there exists considerable variability within this interval. Two new SST reconstructions have been created to provide a climatological error bar for warm peak phases of the Pliocene. These data represent the maximum and minimum possible warming recorded within the 3.3 to 3.0 Ma interval.

PRISM Max-Min Data

The data used for these new reconstructions are identical to those used for the Pliocene Research, Interpretation, and Synoptic Mapping (PRISM) reconstruction (see Dowsett et al., 1999). In the present study, time-series of sea surface temperature (SST) from 77 localities (Figure 1) were analyzed to determine the maximum and minimum warming during the mid Pliocene.

The PRISM2 reconstruction (Dowsett et al., 1999) uses a 'time slab' approach to avoid some of the problems associated with point-to-point correlation between core sequences and land sections in this time interval. The PRISM time slab is defined as the interval lying between the transition of marine oxygen isotope stages M2/M1 and G19/G18 (Shackleton et al., 1995) in the middle part of the Gauss Normal Polarity Chron (C2An) (Figure 2). The reconstruction spans the interval of 3.29 Ma to 2.97 Ma (Berggren et al., 1995; Shackleton et al., 1995; Lourens et al., 1996). It ranges from near the bottom of C2An1 (just above Kaena reversed polarity) to within C2An2r (Mammoth reversed polarity). This interval correlates to planktonic foraminiferal zones PL3 and PL4 or *Globorotalia margaritae-Sphaeroidinellopsis seminulina* and *Dentoglobigerina altispira-Globorotalia pseudomiocenica* planktic foraminiferal zones of Berggren (1973, 1977). It falls within calcareous nannofossil zone NN16 of Martini (1971) or CN12a of Bukry (1973, 1975).

Figure 3 illustrates the peak averaging technique used by PRISM (Dowsett and Poore, 1991, Dowsett et al., 1994; 1996; 1999; Dowsett in prep.) and

its relationship to minimum and maximum warming. In the example shown, five warm peaks indicated by arrows are identified. The communality estimate, a statistical measure of how well the chosen factor model explains the down-core assemblage data, is used to measure the performance of the factor analytic transfer function. In this example, any SST estimate associated with a communality less than the threshold of 0.85 is considered unreliable; thus only four of the five warm peaks are averaged to give a "warm peak average" temperature of ~22.8°C. For the present study, the maximum warm peak (max) and minimum warm peak (min) meeting the communality criteria were also recorded.

As with the PRISM2 SST reconstruction, SST anomalies, determined by calculating differences between MAX or MIN Pliocene estimates and modern temperatures at the location of each site, were plotted as individual points on a 2°x2° grid representing the Earth. Modern SST contours served as a rough guide in the drawing of mid Pliocene SST contours around the control points, because it was assumed that the general pattern of modern oceanic surface current systems was present in the mid Pliocene. Boundaries between anomaly bands were smoothed so as to make even temperature gradients. Finally, this smoothed, contoured anomaly field was added to the modern SST of Reynolds and Smith (1995) to create mid Pliocene MAX and MIN data sets.

Because we estimated winter and summer SST (February and August), we produced two primary Pliocene SST maps for both the MAX and MIN reconstruction (Figures 4-7). The remaining 10 months of the year were constructed by fitting a sine curve to the February and August SST estimates (Dowsett et al., 1996). New data on sea-ice distribution are not yet available. For the MAX SST reconstruction, sea-ice was shifted by one month to produce less monthly sea ice and a longer period of summer ice free conditions in the northern hemisphere with respect to the PRISM2 reconstruction. The MIN SST reconstruction is not that much cooler than PRISM2, therefore no changes were made to the MIN sea-ice configuration.

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Figures

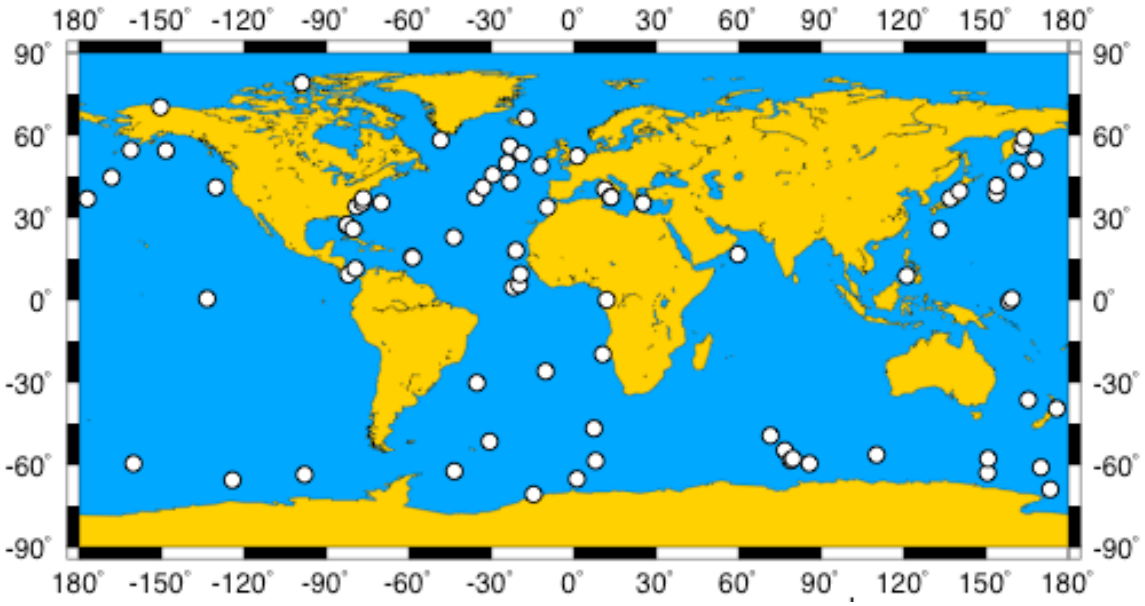

Figure 1. Map showing data localities used in this reconstruction.

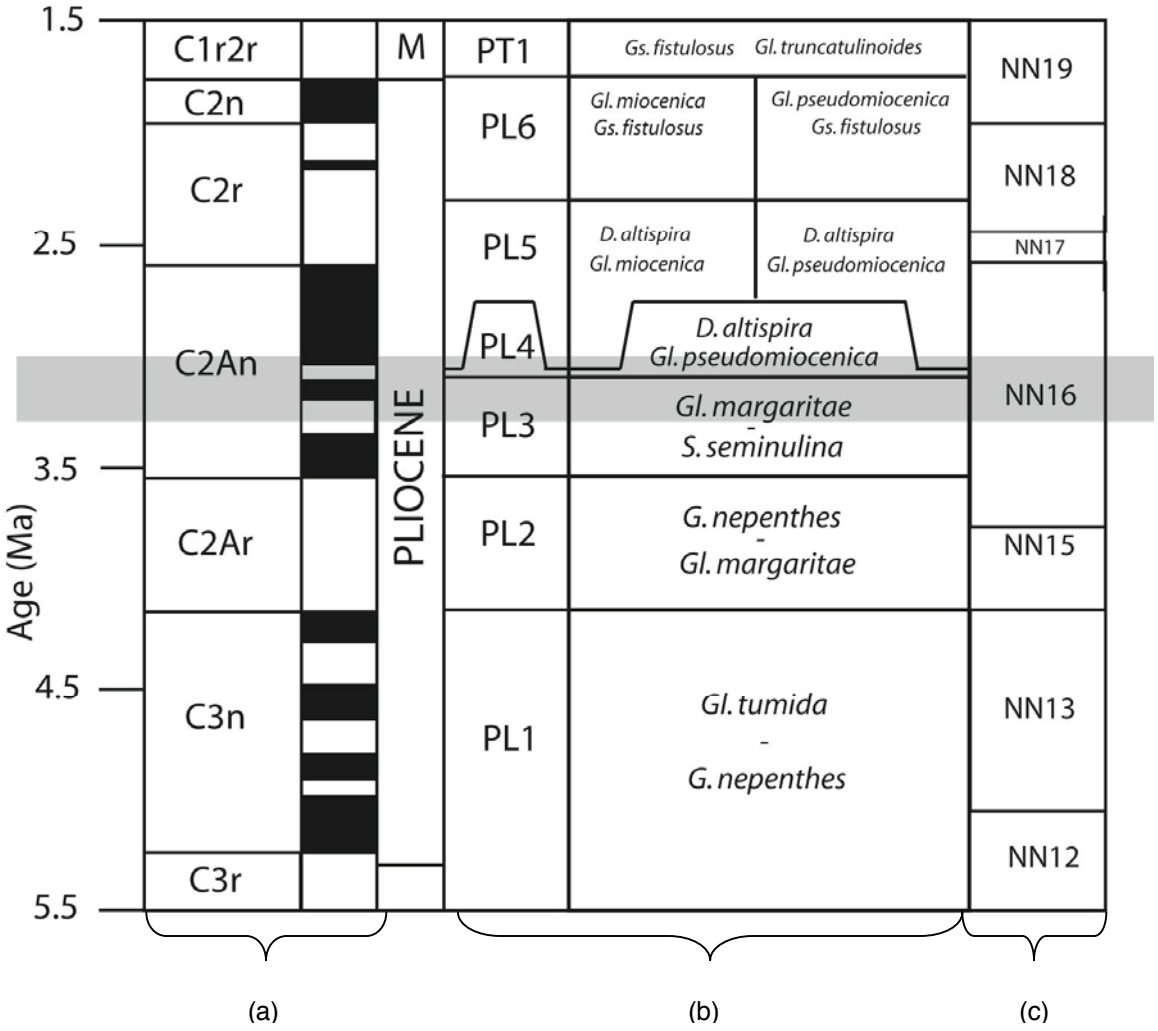

Figure 2. Correlation diagram showing position of PRISM time slab interval (gray band) with respect to geomagnetic polarity (a), planktonic foraminiferal zones (b), and calcareous nannofossil zonation (c). See text for further explanation.

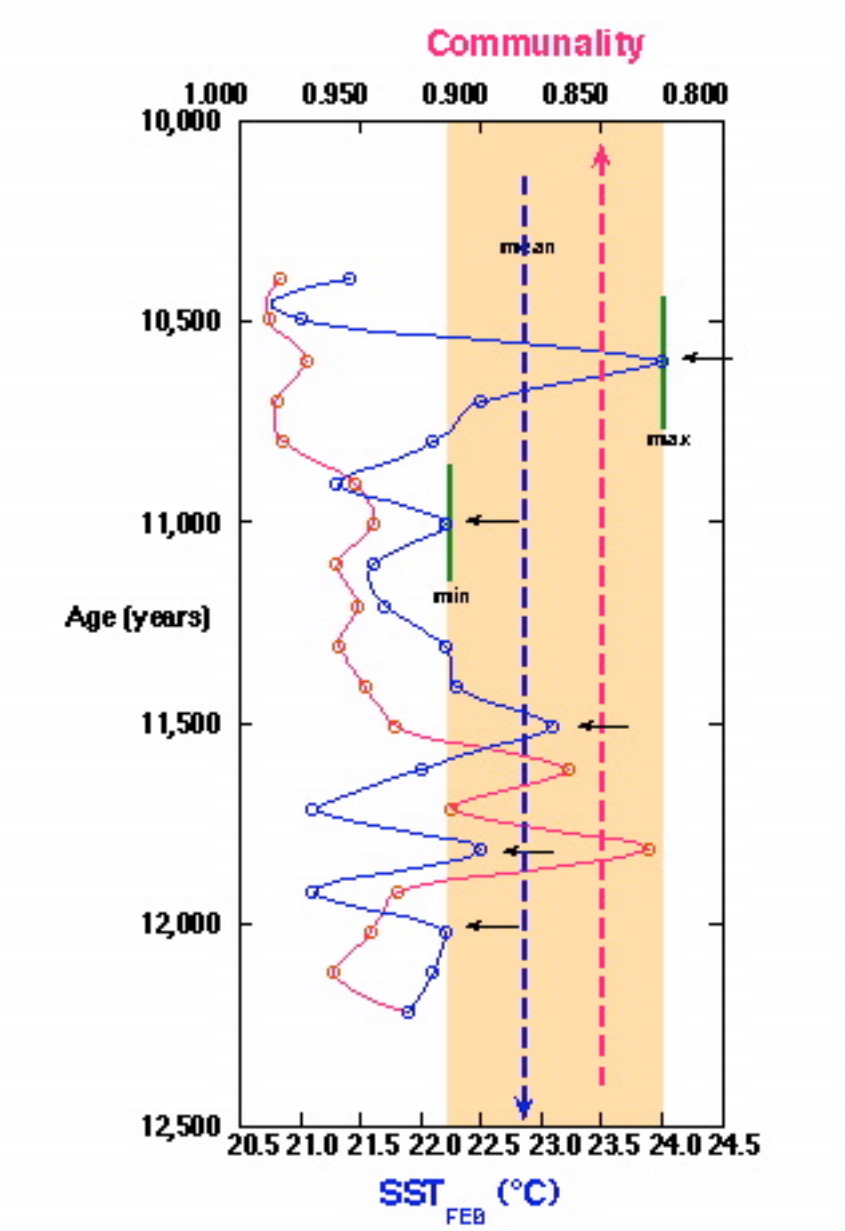

Figure 3. SST time series showing derivation of warm maximum, minimum, and peak averages. Blue series = SST record; Red series = communality estimates; Red vertical dashed line = communality threshold; arrows = identified warm peaks. Green vertical bars represent maximum and minimum warming established for time series. Vertical blue dashed line indicates calculated warm peak average (see Dowsett and Poore, 1991; Dowsett et al., 1999; Dowsett, in prep.).

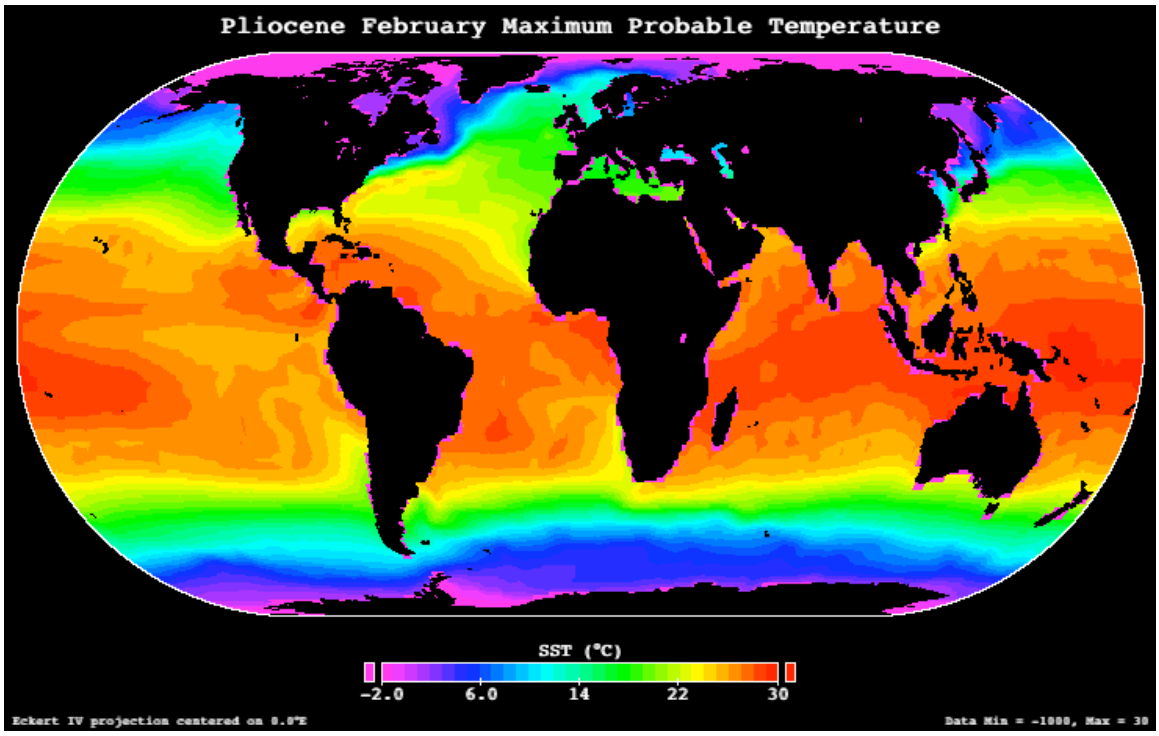

Figure 4. Map showing Pliocene February Maximum SST reconstruction.

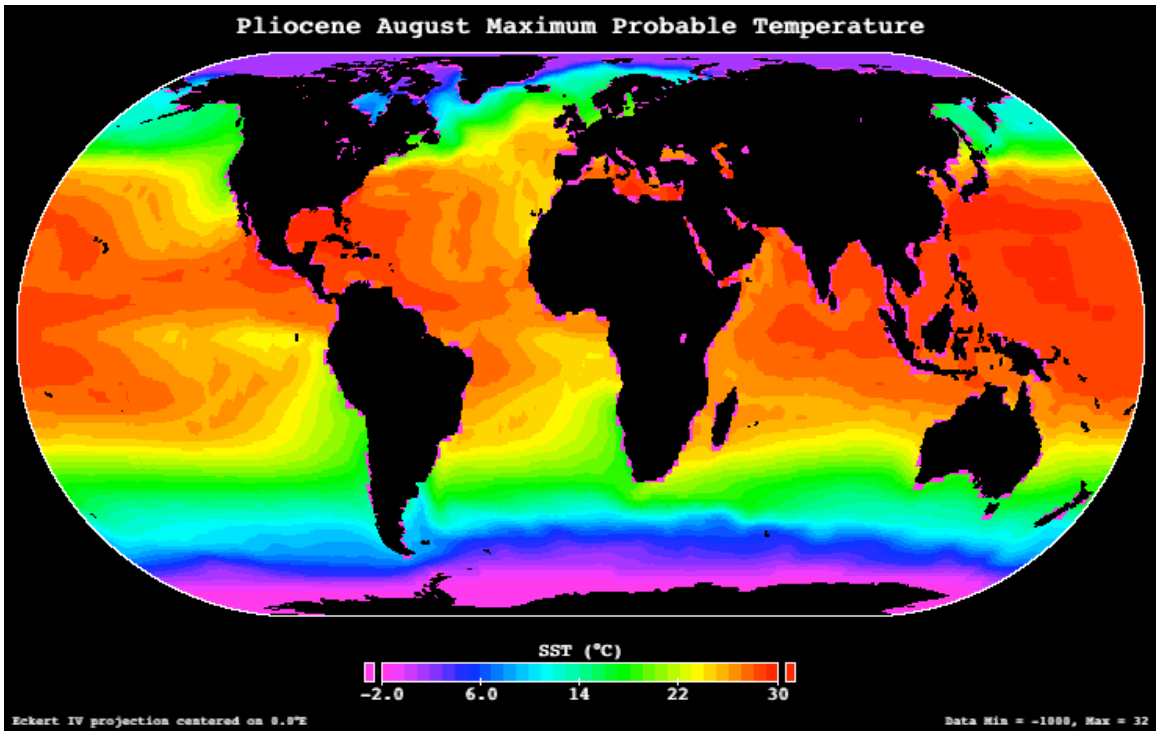

Figure 5. Map showing Pliocene August Maximum SST reconstruction.

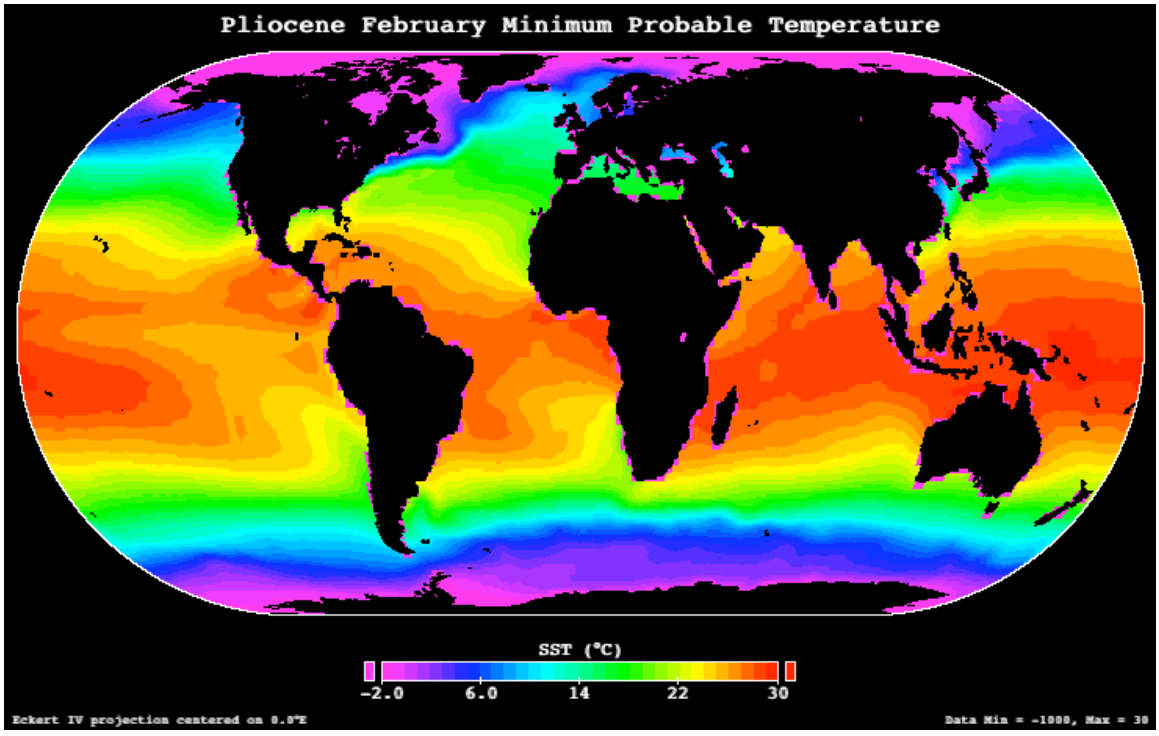

Figure 6. Map showing Pliocene February Minimum SST reconstruction.

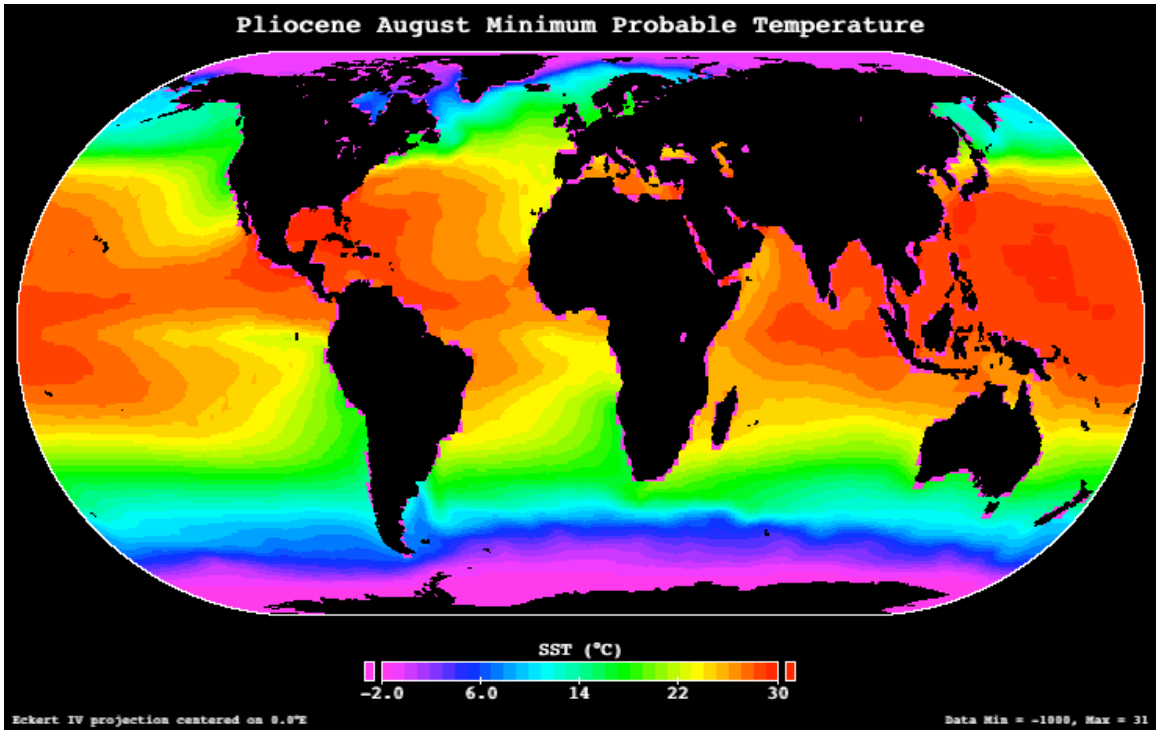

Figure 7. Map showing Pliocene August Minimum SST reconstruction.

Data

The MAX and MIN SST reconstructions are presented in the same manner as the PRISM2 reconstruction. The data are arranged in a matrix of 90 rows by 180 columns, representing a 2°x2° grid of the Earth. Each cell in the 2°x2° global grid designated as water is given a SST in degrees Celsius. Cells designated as land are given the code -999. Sea-ice is designated with SST set to -1.8°C. The MAX and MIN reconstructions exist as two Microsoft® Excel files, each containing one matrix for each month of the year, arranged as worksheets. Readers are urged to consult Dowsett et al. (1999) for more details.

The data can be found here:

http://pubs.usgs.gov/ds/2004/114/

or by contacting the author, hdowsett@usgs.gov.